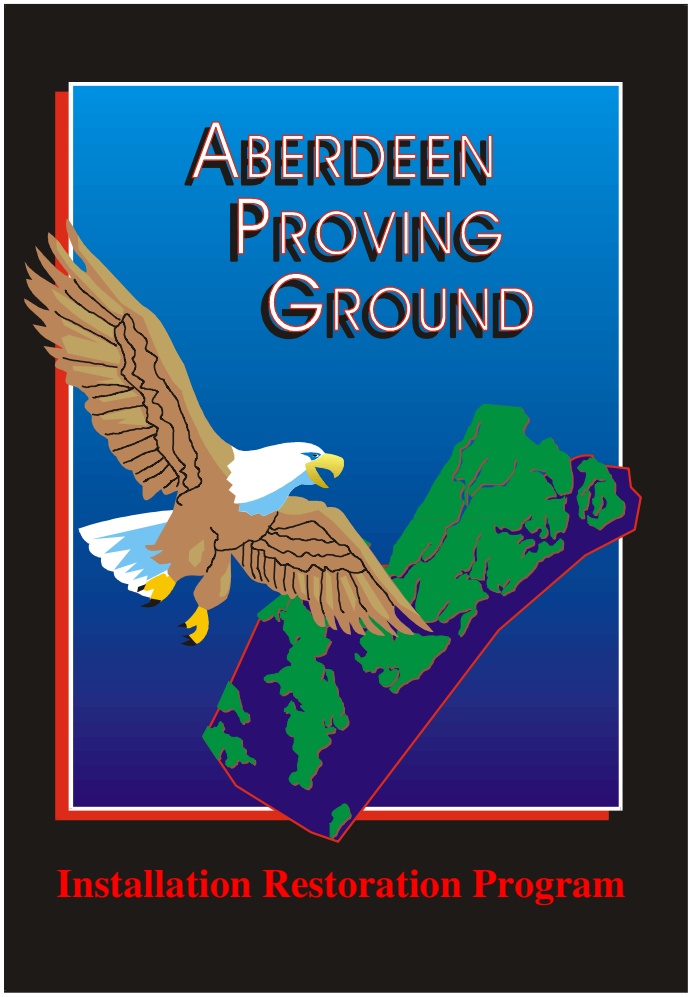

GRACES QUARTERS (OPERABLE UNIT A) PRIMARY TEST AREA

Proposed Plan for Remedial Action

Final

April 2004

U.S. Army Garrison
Aberdeen Proving Ground, Edgewood, Maryland

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This document is the Proposed Plan for Remedial Action for Operable Unit A: Groundwater at Graces Quarters, Aberdeen Proving Ground, Maryland. The purpose of this document is to present the remedial alternatives analyzed for addressing the contaminated groundwater at Graces Quarters and identify the preferred alternative to reduce risks posed by the site.

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Proposed Plan for

REMEDIAL ACTION
ABERDEEN PROVING GROUND, EDGEWOOD
GRACES QUARTERS (OPERABLE UNIT A: GROUNDWATER)
PRIMARY TEST AREA

Aberdeen Proving Ground, Maryland
December 2003

This document is intended to comply with the National Environmental Policy Act in accordance with Army Regulation 200-2

INTRODUCTION AND PURPOSE

The U.S. Department of the Army at Aberdeen Proving Ground (APG), the U.S. Environmental Protection Agency (EPA), and the State of Maryland Department of the Environment (MDE) invite public comment on this Proposed Plan for remedial action to address contaminated groundwater (Operable Unit A) associated with the Primary Test Area at Graces Quarters. Graces Quarters is located in the Edgewood Area of APG, Maryland, and is listed on the **National Priorities List (NPL)*.**

This Proposed Plan describes the remedial alternatives analyzed for the Primary Test Area at Graces Quarters, identifies the preferred alternative to reduce risks posed by the site, and provides justification for this initial recommendation. The plan is intended to summarize, for public review, the conditions at this site and the comparative analysis of different methods for site remediation. It provides the public with information necessary to participate -- with APG and the regulators -- in selecting the most appropriate remedy for the Primary Test Area.

The Primary Test Area was identified as Site 5 followed by **Defense System Environmental Restoration Tracking System (DSERTS)** number EAGQ02-D, while the impacted groundwater below the site was evaluated as Operable Unit A in the **Remedial Investigation (RI)** of Graces Quarters (APG, 1998a). Chlorinated volatile organic compounds (VOCs) -- carbon tetrachloride, 1,1,2,2-tetrachloroethane, trichloroethene, chloroform and tetrachloroethene -- are the major contaminants that potentially pose a threat to human health and the environment. **Chemical Warfare Materiel (CWM)**, **unexploded ordnance (UXO)** and hazardous substances, may also be encountered at the Primary Test Area and will be managed in accordance with the previously submitted and approved **Record of Decision (ROD)** (APG, 2001a) for Operable Unit B (CWM). Remedial Action is required for this site because the potential exists for future exposure of human receptors. Additionally, there is the potential for transport of contaminants to wetlands and the Chesapeake Bay.

The remedial alternatives evaluated for the Primary Test Area, as detailed in the **Feasibility Study (FS)** Report (APG, 2003), include:

Alternative 1: No action.

Alternative 2: Institutional controls/long-term monitoring (LTM).

Alternative 3: Vitamin B_{12}-catalyzed reductive dehalogenation in areas greater than 1,000 micrograms per liter (µg/L); monitored natural attenuation (MNA) at all other locations.

Alternative 4: Vitamin B_{12}-catalyzed reductive dehalogenation in areas greater than 1,000 µg/L; pump-and-treat at all other locations.

Alternative 5: Vitamin B_{12}-catalyzed reductive dehalogenation in areas greater than 1,000 µg/L in the surficial aquifer; pump-and-treat at all other locations.
Alternative 6: Vitamin B_{12}-catalyzed

*This document includes a glossary of terms in bold type.

reductive dehalogenation in areas greater than 100 µg/L (both aquifers); MNA at all other locations.

Alternative 7: Pump-and-treat at all locations.

Alternative 8: Pump-and-treat at areas greater than 1,000 µg/L (both aquifer); LTM at all other locations.

Alternative 9: Electrical resistance heating (ERH) in areas greater than 1,000 µg/L in the surficial aquifer; pump-and-treat at all other locations.

For the site conditions at the Primary Test Area, Alternative 3 is preferred as it is aggressive and more cost effective than the other alternatives except Alternatives 1, 2, and 8 which are judged to be ineffective at achieving **Remedial Action Objectives (RAOs)**. Alternative 3 is protective of human health and the environment; provides long- and short-term effectiveness; reduces the toxicity, mobility and volume of hazardous constituents; and complies with all **Applicable or Relevant and Appropriate Requirements (ARARs)**. The application of vitamin B_{12} as a catalyst or coenzyme for dechlorination of chlorinated VOCs has been tested at the Primary Test Area during a pilot test study conducted by URS Group, Inc. between 1999 and 2000 (APG, 2001b). Following the introduction of reduced vitamin B_{12} into the aquifer, highly chlorinated compounds (parent compounds) were degraded effectively to compounds that were then demonstrated to degrade via abiotic or biotic reactions. Evaluation of site data indicates that MNA may be used as a follow-up in the lower concentration portions of the contaminant plume after active remedial actions have been taken to degrade the highly chlorinated compounds in areas with high concentrations of VOCs (APG, 1999).

The public is encouraged to review the RI and FS Reports, and **Administrative Record** file for more comprehensive understanding of the site and the environmental activities conducted to date. The locations, contact information and hours of operation for the administrative record file are as follows:

Harford County Library – Aberdeen Branch
21 Franklin Street
Aberdeen, MD 21001
(410) 273-5608
Hours: Mon., Tues., Thur. - 10 a.m. to 8 p.m.
Wed. - 1 p.m. to 8 p.m.
Fri., Sat. - 10 a.m. to 5 p.m.
Sun. - 1 p.m. to 5 p.m. (Oct-May only)

Harford County Library – Edgewood Branch
2205 Hanson Road
Edgewood, MD 21040
(410) 612-1600
Hours: Mon., Tues., Thur. - 10 a.m. to 8 p.m.
Wed. - 1 p.m. to 8 p.m.
Fri., Sat. - 10 a.m. to 5 p.m.
Sun. - closed

Kent County – Washington College
Miller Library
Chestertown, MD 21620
(410) 778-2800
Hours: Mon. to Fri. - 8 a.m. to 12 a.m.
Sat. - 10 a.m. to 10 p.m.
Sun. - 11:45 a.m. to 12 a.m.

Baltimore County Public Library - Essex Branch
1110 Eastern Boulevard
Essex, Maryland 21221
(410) 887-0295
Hours: Mon. to Thur. - 10 a.m. to 9 p.m.
Fri., Sat. - 10 a.m. to 5:30 p.m.
Sun. - closed

The Army is the Lead Agency for this Action. This document is issued by the Army (the site owner) with the concurrence of EPA (the lead regulatory agency for site activities) and MDE (the support agency for the sites). Based on new information that may become available, or on public comments, the Army and EPA, in consultation with MDE, may modify the preferred alternative outlined in this plan or incorporate a new remedy for Graces Quarters prior to preparing the ROD. Therefore, the public is encouraged to review and comment on all the alternatives discussed herein.

The Army issues this Proposed Plan as part of its public participation responsibilities under Section 117 (a) of the **Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)** as amended by the

Superfund Amendments and Reauthorization Acts (SARA), commonly known as the "Superfund Program".
A public comment period will extend from April 14 to May 29, 2004. This period will include a public meeting during which the Army, EPA, and MDE will present this Proposed Plan and answer questions. The public meeting is scheduled for Tuesday, April 27 at the Marshy Point Nature Center, 7130 Marshy Point Road, Baltimore, MD 21220. An information/poster session at 6:30 p.m. will be followed by a presentation at 7:15 p.m.

SITE BACKGROUND

APG is a 72,500-acre Army installation located in southern Harford County and southeastern Baltimore County, Maryland, on the western shore of the Upper Chesapeake Bay.

Graces Quarters is bordered to the east and south by the Chesapeake Bay; to the west by Gunpowder Falls State Park, and residential areas; and to the north by the towns of Edgewood, Joppa, Magnolia, and Aberdeen. The Bush River divides APG into the Edgewood Area to the west of the river and the Aberdeen Area to the east. Carroll Island and Graces Quarters (Figure 1) are located in the Edgewood Area; both are listed on the NPL.

Graces Quarters is a peninsula located approximately five miles southeast of White Marsh, Maryland, and two miles southeast of Chase, Maryland, as shown in Figure 1. Access to the property is controlled by chain link fences, a locked gate, and patrols by military police. Paved and gravel roads are present on the peninsula. The only current permanent large structure is an emergency radio transmitter and tower originally constructed by the Federal Emergency Management Agency. Graces Quarters covers 414 acres, of which approximately 151 acres (36 percent) are classified as wetlands. The land mass consists of tidal and nontidal wetlands, open fields, and wooded areas. Maximum elevation is approximately 40 feet (ft) above National Geodetic Vertical Datum (NGVD).

Graces Quarters was acquired as U.S. Army property in 1918 as part of the original Edgewood Arsenal (AEHA, 1989). Little documentation is available on the use of Graces Quarters prior to the 1940's, but it does not appear that there was any Army activity at the site until the 1940's. Records of testing of CWM at Graces Quarters are only available for the period between 1964 and 1971; however, it is known that testing was conducted before this time. Outdoor testing of lethal CWM ceased in 1969. Open-air testing of simulants and non-lethal incapacitants continued at Graces Quarters until 1971, at which time all open-air testing of CWM ceased at the site. Detailed descriptions of the history and land use of Graces Quarters are presented in the **Resource Conservation and Recovery Act (RCRA)** Facility Assessment (AEHA, 1989) and the RI Report (1998a). Graces Quarters is expected to remain under military authority with limited military training activities currently being conducted.

The bulk of the CWM testing took place at the Primary Test Area, which is approximately 22 acres and is classified predominantly as uplands. No structures are present at this site, and it is currently an open, grassy area. The site has gently sloping relief, ranging between 5 to 20 ft above NGVD, and slopes toward the southwest. The Primary Test Area is located near the middle of the Graces Quarters peninsula and is bounded to the east by the Gunpowder River and the Northern Perimeter Dump; to the south by the Southern/Southwest Perimeter Dumps; to the west by the Dugway Proving Ground Test Site and a north-south access road; and to the north by the east-west access road across Graces Quarters (Figure 2). A small amount of testing was also conducted in the small wooded area southwest of the Primary Test Area. The Mustard Gas (2,2'-dichlorodiethyl sulfide or HD) Test Annuli located north of the Primary Test Area were used in decontamination studies with HD, o-ethyl-s- (2-diisopropylaminoethyl)-methylphosphonothioate (VX), and fuming nitric acid. **Surveillance testing** was conducted in the small area southwest of the Graces Quarters Disposal Area. A small amount of testing was also conducted in the Graces Quarters Disposal Area.

Compounds used at Graces Quarters included HD, VX, ortho-chlorobenzolmalonoitrile (CS), isopropylmethylphosphonofluoride (GB), pinacolylmethylphosphonofluoridate (GD), and chlorinated solvents. Wastes from testing activities were disposed of by dumping or burial, primarily at Graces Quarters Disposal Area.

Based on historical uses of Graces Quarters, the principal contaminants that could be present include CWM, explosives, and associated degradation (most likely via hydrolysis reaction) products. In addition, other contaminants that could potentially be present include VOCs, semi-VOCs, pesticides/polychlorinated biphenyls, and inorganics. There exists the potential that some wastes associated with testing and support activities may not have been located/identified, due to the difficulty of detecting these wastes with existing technology. Based on the 1998 RI, the VOC contaminated groundwater beneath the Primary Test Area is designated as Operable Unit A, whereas all CWM and other hazardous substances that have not been located and/or remediated at Graces Quarters are designated as Operable Unit B (APG, 1998a).

A ROD has been prepared and approved to address combined Operable Units B at Graces Quarters and Carroll Island, both of which are similar in the types of contaminants, environment, and potential remedial actions (APG, 2001a). All of the land and shoreline areas are included within the Operable Unit B of Carroll Island and Graces Quarters, and the Selected Remedy -- *Public Access Controls, Land Use Restrictions, and Erosion Controls* – was chosen as the highest level of protection of human health and the environment. A public meeting was held on May 11, 2000 to formally present the Proposed Plan (APG, 2000) for Operable Unit B at Graces Quarters and Carroll Island. EPA and MDE concurred with the Army's preferred alternative, which then became the Selected Remedy in the 2001 ROD (APG, 2001a). The community also agreed with the Selected Remedy. Because the Selected Remedy for Operable Unit B will allow CWM (if any), hazardous substances, and pollutants to remain on site, remedy reviews will be performed every five years, as required by the **National Contingency Plan** (NCP) (APG, 2001a).

Public participation activities related to Graces Quarters include monthly Restoration Advisory Board (RAB) meetings, Aberdeen Proving Ground Superfund Citizens Coalition (APGSCC) meetings, public meetings, as well as press releases, and public access to the APG website.

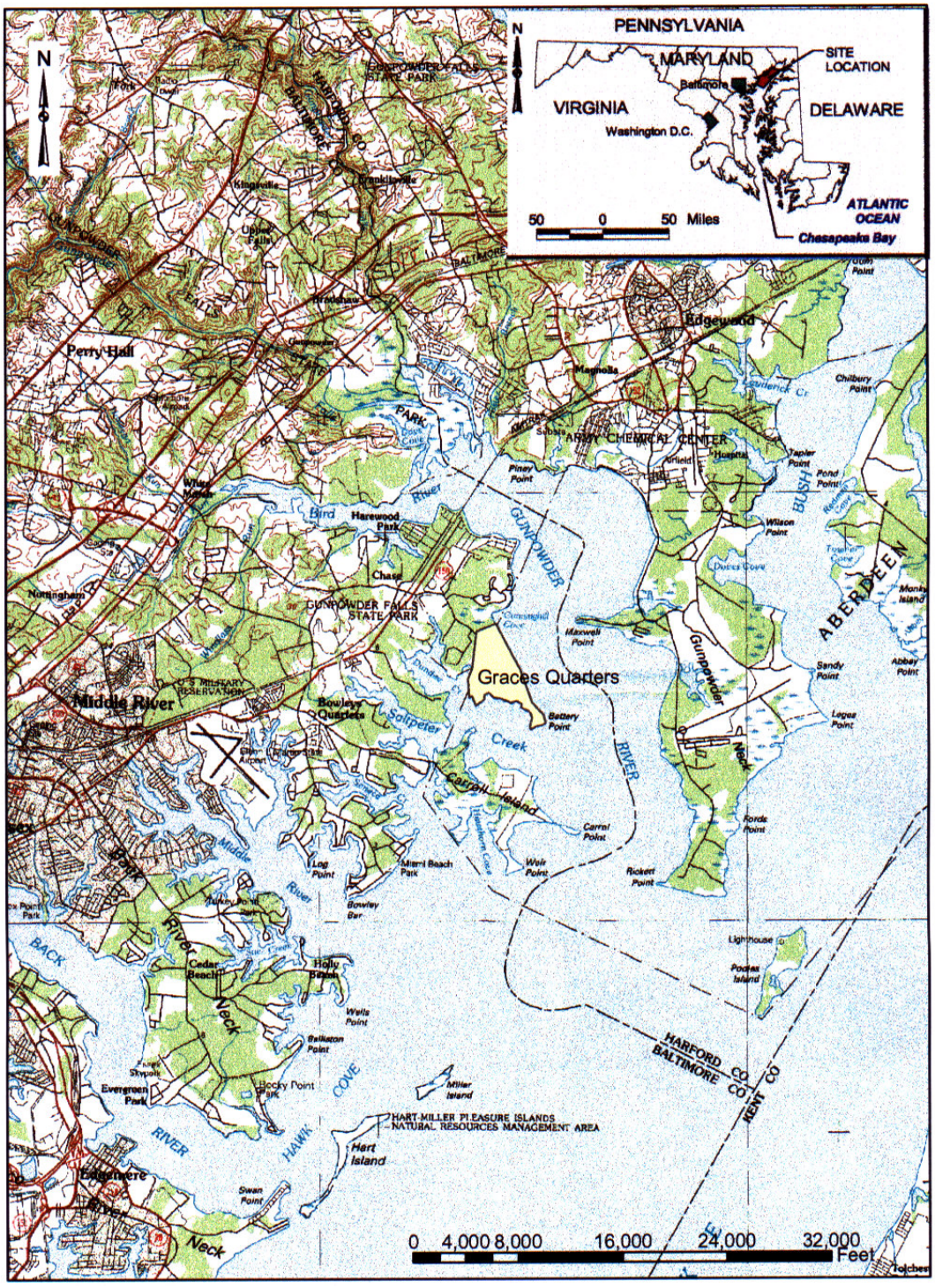

Figure 1. Graces Quarters -- location map.

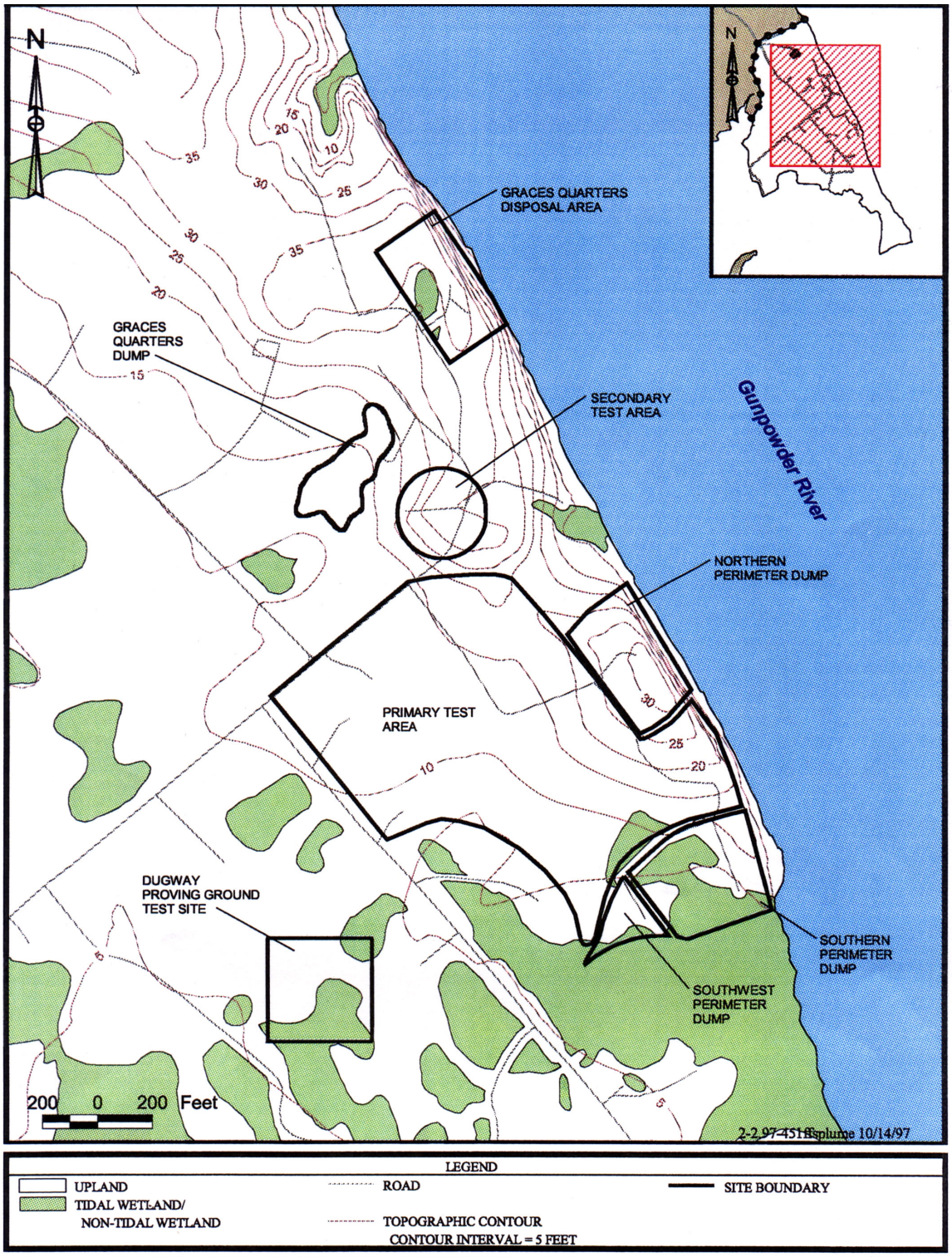

Figure 2. Topographic and site location of the Primary Test Area, Graces Quarters (APG, 1999b).

SITE CHARACTERISTICS

The surficial sediments at Graces Quarters are primarily those of the Patapsco Formation, as described and discussed in the RI Report (APG, 1998a). The clay facies of the Patapsco Formation outcrop mainly in the northeastern part of the peninsula (Bennett and Meyer, 1952), and generally are topographically higher than the rest of Graces Quarters. The sand facies of the Patapsco Formation outcrop in the topographically lower areas of Graces Quarters, and directly underlie the Primary Test Area.

In the Primary Test Area, a surficial unconfined aquifer occurs at the surface and is composed of yellow, clean, fine-to-medium quartz sand with thin layers of silty clay. This surficial aquifer extends to depths approximately 40 to 50 ft below ground surface (bgs) where it is underlain by a discontinuous confining layer that is composed of silty clay. A semi-confined sand unit, termed the middle aquifer, is present from approximately 40 to 80 ft bgs. The middle aquifer predominantly consists of yellow, clean, fine-to-medium quartz sand with thin stringers of silty clay. Beneath the middle aquifer is a continuous clay aquitard.

Groundwater flow in the surficial aquifer is predominantly south and southwest toward the wetland areas located in the southern portion of the peninsula. Surficial groundwater likely discharges to these wetland areas and the surrounding water bodies, and locally recharges the middle aquifer where the middle confining layer is absent. Groundwater in the middle aquifer flows radially away from the holes in the confining layer. It is probable that groundwater in the middle aquifer discharges to the Gunpowder River or Saltpeter Creek. However, because the middle aquifer is deeper and separated from the surface water bodies by clays and silts, it likely takes a longer time to do so than water from the overlaying surficial aquifer. A detailed discussion of the hydrogeology is presented in the Graces Quarters RI (APG, 1998a), the Additional Groundwater Investigations Data Report (APG, 1998b), and the Conceptual Site Model (APG, 2001c).

Groundwater in the surficial and middle aquifer at the Primary Test Area is contaminated with VOCs, particularly chlorinated aliphatic hydrocarbons (CAHs). The most frequently detected contaminants include 1,1,2,2-tetrachloroethane, carbon tetrachloride, tetrachloroethene, chloroform, and trichloroethene. The contaminants have formed a plume of contaminated groundwater originating in the surficial aquifer, migrating to the south, and into the middle aquifer.

Groundwater samples were collected from both geoprobes and monitoring wells. Geoprobes are temporary sampling points and are removed after samples have been collected. The compound detected at the highest concentration was 1,1,2,2-tetrachloroethane at 181,000 µg/L in a groundwater sample from a geoprobe. Confirmed peak detections (repeated detections in permanent wells) of 1,1,2,2-tetrachloroethane are much lower and are on the order of 2,000 to 3,000 µg/L. Carbon tetrachloride, trichloroethene and chloroform were detected in the 1,000 to 3,000 µg/L range, although the majority of the positive detections were below 1,000 µg/L. Tetrachloroethene was detected at lower concentrations than the previously mentioned constituents.

There are no known specific contaminant source areas at Graces Quarters. It is likely that the contaminants were introduced to the surficial aquifer as multiple non-point source releases of solvents used during the testing of CWM. The contaminants have formed a plume of contaminated groundwater originating in the surficial aquifer and migrating to the south and into the middle aquifer through pathways in the confining layer. Based on the distribution of contaminants and detected concentrations, it is believed that residual dense non-aqueous phase liquid (DNAPL) may exist in the surficial aquifer in the area where concentrations exceed 1,000 µg/L total VOCs. This is consistent with the EPA current guidance suggesting DNAPL should be considered as the principal threat and be suspected at areas where the concentration levels of individual constituents exceed one or more percent of their effective solubilities. The EPA guidance also advises using

treatment to destroy principal threats and to contain or use engineering methods to address non-principal threats (e.g., dilute VOC plume).

It is believed that contamination in the middle aquifer has been transported as dissolved phase only and that no residual DNAPL exists in the middle aquifer -- total VOC concentrations in the middle aquifer are typically less than 1,000 µg/L although peak concentrations exceed 3,000 µg/L. Table 1 presents the areal extent and volume of groundwater contamination in the surficial and middle aquifers at various concentration ranges. These estimates are based on calculations using the Groundwater Modeling System (GMS) software, present understanding of contaminant distribution, and a porosity of 20 percent. Figures 3 and 4 show the areal extent of the total VOC plumes in the surficial and middle aquifers, respectively.

Table 1. Areas and volumes of contaminated groundwater in Graces Quarters Operable Unit A – Primary Test Area (APG, 1999).

Concentration Range (Total VOCs)	Area (square feet, ft^2)		Volume (gallons)	
	Surficial Aquifer	Middle Aquifer	Surficial Aquifer	Middle Aquifer
>1000 µg/L	60,200	14,500	2,230,000	524,000
100 - 1000 µg/L	183,000	145,000	4,470,000	3,510,000
5 - 100 µg/L	546,000	1,150,000	16,700,000	35,500,000

SCOPE AND ROLE OF OPERABLE UNIT

An Operable Unit is defined by the NCP as "a discrete action that comprises an incremental step toward comprehensively mitigating site problems". Based on the complexity of the problems -- distinctive nature of contaminants in the soil and the groundwater, and different pathways of exposure -- two Operable Units associated with Graces Quarters were established for the purpose of managing the site-wide response action (APG, 1998a).

- Operable Unit A: Groundwater associated with the Primary Test Area containing primarily chlorinated VOCs.

- Operable Unit B: Entire areas of Graces Quarters addressing all CWM and hazardous substances.

As previously mentioned, Operable Unit B of Graces Quarters was addressed together with Operable Unit B of Carroll Island due to their similarity in the types of contaminants, environment, and potential remedial actions. A separate ROD was prepared and approved, which addresses all CWM and hazardous substances that have not been located at both Graces Quarters and Carroll Island (APG, 2001a).

This Proposed Plan addresses only Operable Unit A of Graces Quarters as the concentrations of chlorinated solvents in the groundwater, primarily 1,1,2,2-tetrachloroethane and carbon tetrachloride in the vicinity of the Primary Test Area, warrant remediation. Residual DNAPL, which based upon the concentrations of total VOCs may exist in localized areas beneath the Primary Test Area, is considered to be a principal threat to human health and the environment. A FS has been prepared to evaluate remedial alternatives addressing the contaminated groundwater (APG, 2003).

The Selected Remedy for Operable Unit A is intended to prevent both human exposure to COCs, and to prevent the migration of COCs from the Primary Test Area at Graces Quarters. The Selected Remedy for Operable Unit A, in particular, is capable of destroying the principal threat wastes via *in-situ* treatment, addressing the diluted plume via natural attenuation, and restoring the aquifers' potential for beneficial use in years to come.

SUMMARY OF SITE RISKS

Risk Assessments (RAs) are usually performed on sites that contain measurable levels of contaminants in environmental media such as soil or groundwater. Using concentrations of contaminants, an

estimated risk to human health and the environment can be quantified.

Human Health Risk Assessment

The purpose of human health risk assessment is to determine whether exposure to site-related contaminants could adversely affect human health. The focus of the human health risk assessment is on the possible human health effects that could occur under current or potential future use conditions in the event that contamination is not remediated. The risk is expressed as lifetime excess cancer risk (LECR) for carcinogens, and hazard index (HI) for noncarcinogens. For example, an LECR of $1x10^{-6}$ represents the probability of one additional cancer, in a population of one million people exposed. A hazard quotient above one presents a likelihood of noncarcinogenic health effects in exposed populations.

The purpose of the human health Baseline Risk Assessment (BRA) for the Primary Test Area of Graces Quarters was to establish the risks and hazards associated with exposure to groundwater. It was determined that under the current land use conditions (groundwater is not in use and there are currently no drinking water wells) exposure to groundwater is unlikely. However, for future land-use, civilian and military workers involved with "military multiple-use" (periodic training and light equipment testing activities) of the Primary Test Area may potentially have contact with site groundwater. For military multiple-use workers, there is exposure potential via ingestion of groundwater as assumed in the RA (the military multiple-use scenario is essentially a light industrial use assessment which has limited groundwater ingestion assumption inherent in the scenario). The calculated carcinogenic risk for this scenario is $4x10^{-3}$ and the noncarcinogenic HI is 30. Table 2 presents the constituents that contributed a risk greater than or equal to $1x10^{-6}$, or HI greater than or equal to 1.0, and their calculated exposure point concentration.

Table 2. Primary constituents contributing to carcinogenic risk or noncarcinogenic hazard under future military multi-use scenario (APG, 1998a).

Constituent[1]	Exposure Point Concentration, µg/L	Contribution to Risk	Contribution to HI
1,1,2,2-TeCA	4,400	$3x10^{-3}$	N/A
1,1,2-TCA	7.21	$1x10^{-6}$	$2x10^{-2}$
1,1-DCE	3.44	$7x10^{-6}$	$4x10^{-3}$
CT	2,000	$9x10^{-4}$	30
CF	22.9	$5x10^{-7}$	$2x10^{-2}$
PCE	27.7	$5x10^{-6}$	$3x10^{-2}$
TCE	850	$3x10^{-5}$	N/A
VC	3.8	$3x10^{-5}$	N/A
Total VOCs		$4x10^{-3}$	30

[1]Acronyms: TeCA, tetrachloroethane; TCA, trichloroethane; DCE, dichloroethene; CT, carbon tetrachloride; CF, chloroform; PCE, tetrachloroethene; TCE, trichloroethene; VC, vinyl chloride.

The carcinogenic risk and noncarcinogenic hazard were also calculated for exposure under a residential land use scenario. While residential land use scenarios are considered unlikely, and the reasonable worst case was assumed to be military multiple-use, residential evaluation was included for comparison purposes and to ensure a complete understanding of the spectrum of risk at the site. Residential risk calculations for comparison purposes were run per EPA policy. However, the industrial use risk assessment is the basis for remedy selection at this site. The calculated carcinogenic risk ($3x10^{-2}$) and the noncarcinogenic HI (100) suggested that the groundwater at Graces Quarters warrants active remedial actions to mitigate risks associated with exposure to the contaminated groundwater. A breakdown of the contribution of individual constituents to the overall residential risk is detailed in the RI (APG, 1998a); the hypothetical residential exposure is unlikely, however.

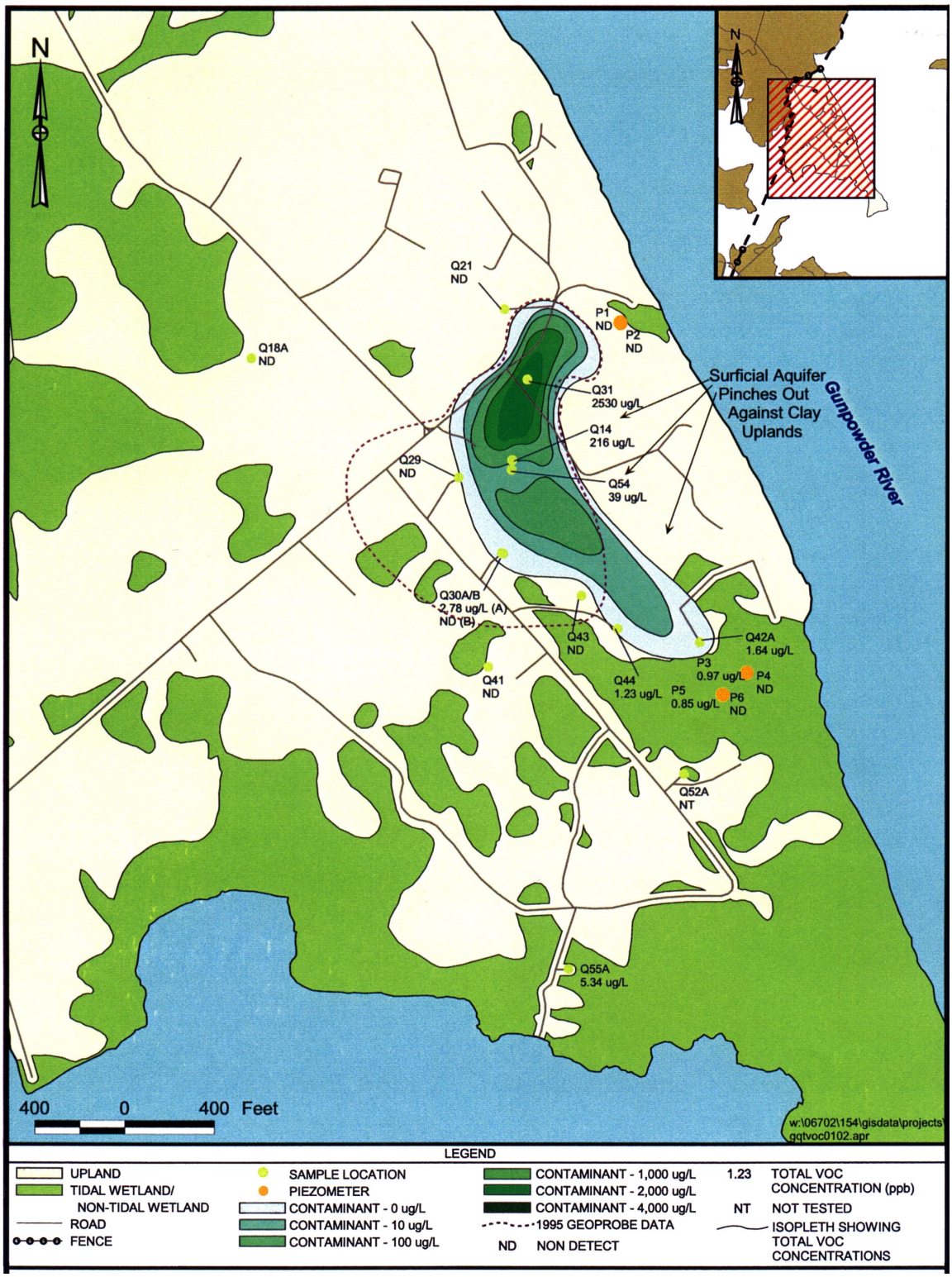

Figure 3. Isopleth map showing the horizontal extent of the total VOC plume in the Surficial Aquifer beneath the Primary Test Area, Graces Quarters (APG, 2001c).

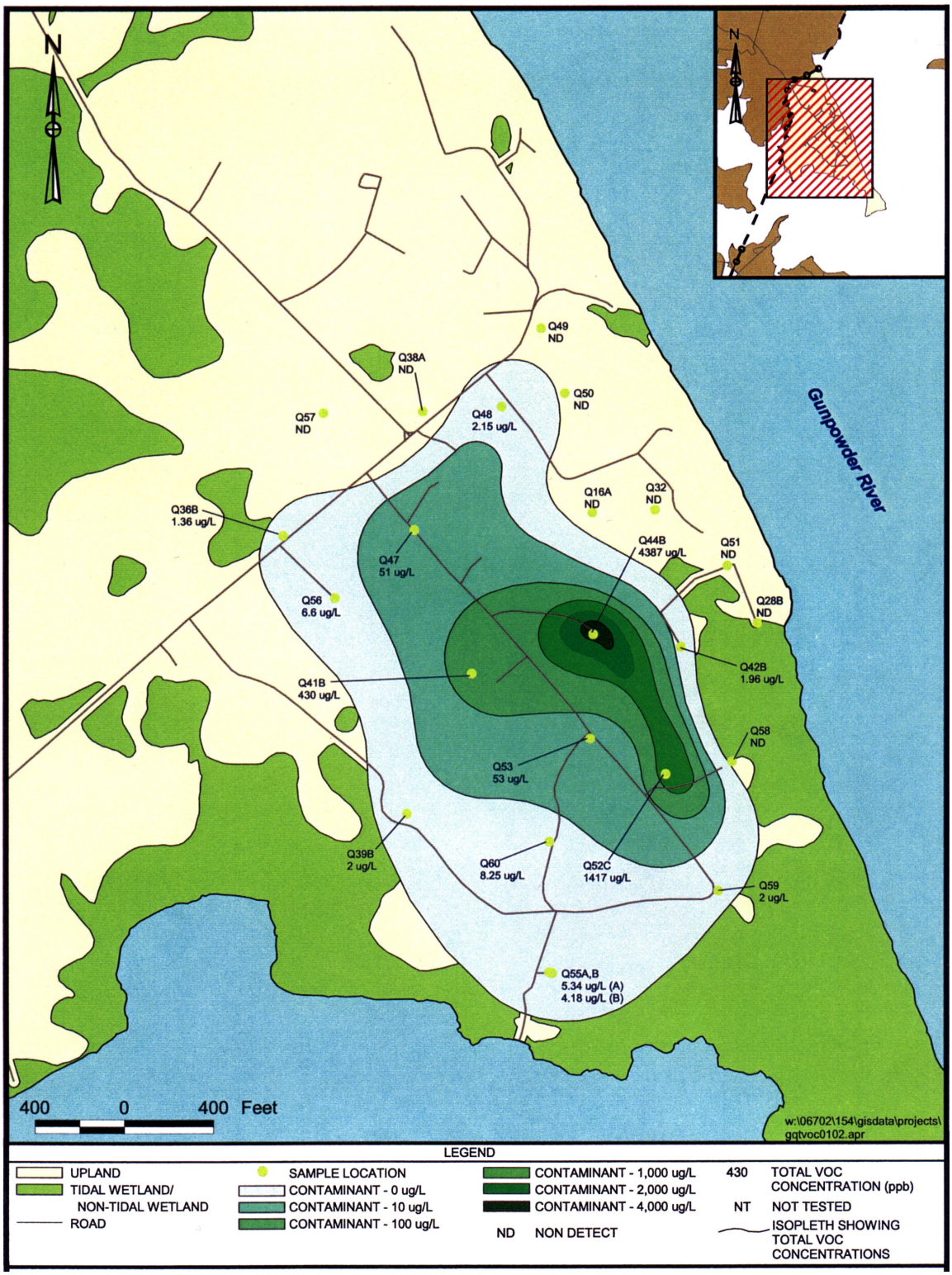

Figure 4. Isopleth map showing the horizontal extent of the total VOC plume in the Middle Aquifer beneath the Primary Test Area, Graces Quarters (APG, 2001c).

Ecological Risk Assessment

An ecological evaluation of Graces Quarters was conducted as part of the RI. Chemical analyses were performed on samples of surface soil, surface water and sediment from freshwater ephemeral ponds, and shoreline surface water and sediment from brackish water habitats (i.e., Saltpeter Creek and Gunpowder River). A survey was also conducted of the terrestrial, wetland, and aquatic flora and fauna of Graces Quarters that could be exposed to constituents of potential concern (COPCs).

Surface soil, ephemeral pond surface water, and ephemeral pond sediment samples were collected from locations within the Primary Test Area and could thus be directly associated with the site. The connection between the shoreline surface water samples and the Primary Test Area is less clear because COPC in these samples may originate from sources other than the Primary Test Area or even other than the Graces Quarters peninsula given the tidal character of the water bodies. Thus there is a qualitative component to the evaluation of the shoreline COPC data with respect to Primary Test Area contribution. Details of the approach used to evaluate each medium are provided in the RI (APG, 1998a).

The ecological risk assessment (ERA) results are summarized as follows:

- During the RI, none of the chlorinated solvents that comprise the plumes in the surficial and middle aquifers were detected in surface soil, ephemeral pond surface water, or ephemeral pond sediment associated with the Primary Test Area.

- No chlorinated solvents were detected in shoreline sediment samples, and only one chlorinated solvent (1,1,1-trichloroethane) was detected in one of the twelve shoreline surface water samples. This detection was five orders of magnitude below the Federal Ambient Water Quality Criteria. The compound 1,1,1-trichloroethane is not a significant component of the chlorinated solvent groundwater plume associated with the Primary Test Area.

- The ERA concluded that based on comparison of the concentrations of chemicals detected in sediment to the available toxicity values, it is reasonable to conclude that no adverse effects are currently occurring to benthic communities from chemicals in sediments from the Primary Test Area.

- The ERA concluded that based on comparison of the concentrations of chemicals detected in surface water to the available toxicity values, it is reasonable to conclude that no adverse effects are currently occurring to aquatic life from chemicals in surface water from the Primary Test Area.

However, predictive groundwater model simulation assuming no remedial action is taken (no source removal and no stimulated natural attenuation), indicates that contaminants would spread throughout various parts of the surficial and middle aquifers, with the 100-year simulation showing potential VOC discharge areas in the marshes south of the Primary Test Area; the marshes at the end of the Graces Quarters; or just offshore in the estuaries (USGS, 2001).

It is the lead agency's current judgment that the Preferred Alternative identified in this Proposed Plan or one of the other active measures considered in the Proposed Plan, is necessary to protect public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment.

REMEDIAL ACTION OBJECTIVES

This Proposed Plan addresses the selection of a remedial alternative, which satisfies specific RAOs determined based on a review of available data and all ARARs. RAOs consist of medium-specific goals for protecting human health and the environment. These objectives can be achieved by reducing exposure (e.g., capping an area or limiting access) as well as by reducing the level of COCs.

There exists the potential for the exposure to contaminated groundwater associated with

the Primary Test Area, although public access controls and land use restrictions are currently in place. Qualitative and quantitative RAOs are established for Operable Unit A to restore the aquifer for beneficial use.

The RAOs for Operable Unit A are as follows:

- Prevent exposure to groundwater from the surficial and middle aquifers until such time as constituent concentrations decline below specified levels in the selected remedial alternative.

- Restore the aquifers' potential for beneficial use by lowering constituent concentrations to acceptable levels, that are established as quantitative RAOs. Quantitative RAOs are developed for groundwater constituents that produce LECRs greater than or equal to $1x10^{-6}$, have a HI greater than 1.0, are present at concentrations above their maximum concentration level (MCL), or are at cleanup levels acceptable to EPA and MDE.

SCREENING OF POTENTIAL CLEANUP ACTIONS

Based on initial screening, the following actions were considered for Operable Unit A:

1. No action (required for comparison)

2. Institutional controls
   - Land use restrictions
   - Groundwater monitoring

3. *In-situ* groundwater treatment
   - In-situ vitamin B_{12}-catalyzed reductive dehalogenation with groundwater recirculation well delivery system
   - ERH intended to volatilize VOCs. The vaporized VOCs are then collected by soil-vapor extraction wells
   - MNA

4. Ex-situ groundwater treatment
   - Vertical extraction wells
   - Air stripping
   - Carbon adsorption

5. Groundwater disposal via surface water discharge

Potentially applicable remedial technologies were identified and screened with respect to their suitability for use at the site. Six remedial technologies passed the screening process and were retained for detailed evaluation: institutional controls, groundwater monitoring, MNA, vitamin B_{12} recirculating wells, pump-and-treat, and ERH. No single technology provides the best mix of attributes for the Primary Test Area. Therefore the remedial technologies were combined to provide a spectrum of nine alternatives, as discussed in the following section.

SUMMARY OF REMEDIAL ALTERNATIVES FOR OPERABLE UNIT A

A summary of the nine remedial alternatives has been developed to provide a conceptual design and cost estimate and allow for evaluation of each alternative with respect to the required evaluation criteria. While this Proposed Plan provides the basis for sound estimates for a preliminary evaluation, additional work would be required to fully assess/design a remedial system on-site. The remedial alternatives generated using the remedial action screening process for the Primary Test Area are summarized as follows:

Alternative 1: No action.

Alternative 2: Institutional controls/LTM.

Alternative 3: Vitamin B_{12}-catalyzed reductive dehalogenation in areas greater than 1,000 µg/L; MNA at all other locations.

Alternative 4: Vitamin B_{12}-catalyzed reductive dehalogenation in areas greater than 1,000 µg/L; pump-and-treat at all other locations.

Alternative 5: Vitamin B_{12}-catalyzed reductive dehalogenation in areas greater

than 1,000 µg/L in the surficial aquifer; pump-and-treat at all other locations.

Alternative 6: Vitamin B_{12}-catalyzed reductive dehalogenation in areas greater than 100 µg/L (both aquifers); MNA at all other locations.

Alternative 7: Pump-and-treat at all locations.

Alternative 8: Pump-and-treat in areas greater than 1,000 µg/L (both aquifers); LTM at all other locations.

Alternative 9: ERH in areas greater than 1,000 µg/L in the surficial aquifer; pump-and-treat at all other locations.

Institutional controls and groundwater compliance monitoring are included for each alternative except Alternative 1. These controls may include appropriate warning signs, and land and water patrols. Land use restrictions will be placed on the Primary Test Area to prohibit the unauthorized extraction and use of groundwater. Residential or military residential housing, and extraction/use of groundwater will be prohibited. Annual site inspections will be conducted to ensure these controls are in place.

UXO screening/clearance are required for all intrusive activities occurring at the site, but are not otherwise addressed under Operable Unit A. These issues are addressed by the Selected Remedy for Operable Unit B -- *Public Access Controls, Land Use Restrictions, and Erosion Controls* -- as detailed in the ROD for Carroll Island and Graces Quarters Operable Unit B (APG, 2001a).

Alternative 1: No Action

Estimated Capital Cost: $0
Estimated Present Worth O & M Cost: $0
Estimated Total Present Worth Cost: $0
Estimated Time to Achieve RAOs: Will not Achieve RAOs

The EPA FS process requires that a "no action" alternative be evaluated as a basis for comparing alternatives. Although security patrols are presently conducted at APG and warning signs exist, no "additional" action is taken. Therefore, no efforts are undertaken to locate or prevent exposure to CWM and other hazardous substances. This alternative is used for comparison purposes to evaluate other alternatives. Under the No Action alternative for Graces Quarters Operable Unit A, no remedial efforts would be made to control risks to human or ecological receptors; treat or remove waste; or reduce the toxicity, mobility, or volume of contaminated media. Institutional actions (such as land use restrictions) would not continue. There are no cost associated with capital, O&M and **net present worth**.

Alternative 2: Institutional Controls/LTM

Estimated Capital Cost: $0
Estimated Present Worth O & M Cost: $400,000
Estimated Total Present Worth Cost: $400,000
Estimated Time to Achieve RAOs: undefined

With this alternative, no actions are conducted to remediate groundwater contamination at the site. This alternative does include institutional controls that will be implemented at Graces Quarters as part of the Selected Remedy -- *Public Access Controls, Land Use Restrictions, and Erosion Controls* -- as detailed in the ROD for Carroll Island and Graces Quarters Operable Unit B (APG, 2001a). Appropriate access controls will include warning signs, and land and water patrols. Land use restrictions will be placed on the Primary Test Area to prohibit the unauthorized extraction and use of groundwater. Residential or military residential housing, and extraction/use of groundwater will be prohibited. Annual site inspections will be conducted to ensure these controls are in place.

This alternative also includes LTM of groundwater at the Primary Test Area. Annual groundwater monitoring will be performed to document the plume configuration and concentration. The design workplan will outline the wells to be sampled, sample analysis, contingency

plans, and criteria for discontinuation of the monitoring program. As discussed in the FS Report, groundwater monitoring will consist of sampling 20 compliance wells for VOCs annually. An annual report will present the data results and describe the plume configuration, migration, and change in contaminant levels.

Alternative 3: Vitamin B_{12}-catalyzed reductive dehalogenation in areas greater than 1,000 µg/L; MNA at all other locations

Estimated Capital Cost: $2,111,496
Estimated Present Worth O & M Cost: $3,588,504
Estimated Total Present Worth Cost: $5,700,000
Estimated Time to Achieve RAOs: 30 years

Alternative 3 involves treating areas with VOC concentrations greater than 1,000 µg/L with vitamin B_{12} concentrate and using MNA where concentrations are less than 1,000 µg/L. Land use restrictions (described in Alternative 2) will be enforced to prevent exposure to groundwater contaminants until remediation goals are achieved.

The vitamin B_{12} treatment technology has been demonstrated during a pilot study conducted at the Primary Test Area from September 1999 to December 2000 (APG, 2001b). The technology introduces a buffered solution of vitamin B_{12}, titanium citrate, and other carbon substrates into the subsurface. The vitamin B_{12} concentrate will be introduced into the subsurface via a recirculation well or other alternative methods such as direct injection or injection through standard wells. Vitamin B_{12} is a transitional-metal coenzyme containing a cobalt atom in the center of the molecule that, in a chemically reducing environment, catalyzes dechlorination of CAHs. The vitamin B_{12} treatment technology is expected to reduce the total VOCs concentrations to below 100 µg/L in the treatment zone within five years.

Effective treatment of the hot spot areas will facilitate the use of MNA to remediate areas of the plume where concentrations are less than 1,000 µg/L. In addition to source treatment, the addition of vitamin B_{12} concentrate is expected to expand the extent of the chemical reducing zones beyond the immediate treatment area over time as the vitamin B_{12} is transported through the aquifer beyond the initial treatment areas. Reduction in contaminant concentrations by natural attenuation will be documented and evaluated through a MNA monitoring program to be specified in the design workplan. The achievement of MCLs or residential RBCs for the COCs would be the performance standard that triggers a termination of the MNA monitoring program. It is anticipated that the duration of vitamin B_{12} injections will be about a year and that the requirement of MNA monitoring will be less than 30 years.

Alternative 4: Vitamin B_{12}-catalyzed reductive dehalogenation in areas greater than 1,000 µg/L; pump-and-treat at all other locations

Estimated Capital Cost: $3,324,793
Estimated Present Worth O & M Cost: $6,075,207
Estimated Total Present Worth Cost: $9,400,000
Estimated Time to Achieve RAOs: 20 years

Alternative 4 involves treating areas with VOC concentrations greater than 1,000 µg/L with the vitamin B_{12} concentrate as detailed under Alternative 3. Groundwater extraction and surface treatment by conventional technologies will be used where concentrations are less than 1,000 µg/L. To capture the groundwater plume where concentrations are between 5 and 1,000 µg/L, groundwater will be extracted, treated above ground using air stripping and carbon adsorption, and discharged to the Gunpowder River under National Pollutant Discharge Elimination System (NPDES) equivalency permit using MDE approved discharge parameters. Conventional or horizontal extraction wells would be used as needed to capture this groundwater.

The vitamin B_{12} treatment technology is expected to reduce the total VOC concentrations to below 100 µg/L, in the treatment zone within five years. The performance standard that triggers a shut

down of the pump-and-treat operation will be based upon the achievement of MCLs or residential RBCs for the COCs. A monitoring program will be specified in the design workplan.

Alternative 5: Vitamin B_{12}-catalyzed reductive dehalogenation in areas greater than 1,000 µg/L in the surficial aquifer; pump-and-treat at all other locations

Estimated Capital Cost: $2,471,264
Estimated Present Worth O & M Cost: $6,128,736
Estimated Total Present Worth Cost: $8,600,000
Estimated Time to Achieve RAOs: 30 years.

Alternative 5 combines vitamin B_{12}-catalyzed reductive dechlorination in areas greater than 1,000 µg/L in the surficial aquifer with pump-and-treat for the remaining areas of the plume, including areas in the middle aquifer greater than 1,000 µg/L. The vitamin B_{12} component of Alternative 5 is similar to that described for Alternatives 3 and 4. However, this alternative only delivers vitamin B_{12} concentrate using recirculation wells in the surficial aquifer plume in areas with total VOC concentrations above 1,000 µg/L.

The groundwater extraction and treatment component of Alternative 5 is the same as that described for Alternative 4, capturing groundwater with VOC concentrations between 5 and 1,000 µg/L. For the middle aquifer, this alternative includes groundwater extraction and treatment for all contamination above 5 µg/L. As described in Alternative 4, extracted groundwater will be treated above ground using air stripping and carbon adsorption, and then discharged to the Gunpowder River under NPDES equivalency permit using MDE approved discharge parameters.

The implementation of vitamin B_{12} treatment technology is expected to reduce the total VOC concentrations in the surficial aquifer to below 100 µg/L within five years. The performance standard that triggers a shut down of the pump-and-treat operation in both surficial and middle aquifers will be based upon the achievement of MCLs or residential RBCs for the COCs. A monitoring program will be specified in the design workplan.

Alternative 6: Vitamin B_{12}-catalyzed reductive dehalogenation in areas greater than 100 µg/L (both aquifers); MNA at all other locations

Estimated Capital Cost: $5,304,838
Estimated Present Worth O & M Cost: $8,995,162
Estimated Total Present Worth Cost: $14,300,000
Estimated Time to Achieve RAOs: 20 years

The vitamin B_{12} component of Alternative 6 is similar to that described for Alternative 3. However, Alternative 6 includes vitamin B_{12} treatment in areas of the plume, in both the surficial and middle aquifers, where total VOC concentrations exceed 100 µg/L. The vitamin B_{12} system represented here is conceptually the same as for Alternative 3 other than the increased number of wells required to treat the larger area, the increased flow rate, and an increased amount of vitamin B_{12} concentrate used. Additionally, a pipeline installed three feet underground may be necessary to supply the vitamin B_{12} concentrate to the delivery wells under this alternative.

MNA will be used to remediate areas of the plume where total VOC concentrations are less than 100 µg/L. It is important to note that the addition of the vitamin B_{12} concentrate is expected to expand the extent of the strong reducing zone beyond the treatment area over time as the vitamin B_{12} concentrate is transported through the aquifer beyond the delivery well capture area. Reduction in contaminant concentrations by natural attenuation will be documented and evaluated through a MNA monitoring program to be specified in the design workplan.

The vitamin B_{12} treatment technology is expected to significantly reduce the total VOC concentrations in both the surficial and middle aquifers to below 100 µg/L in about five years. Following the termination of the vitamin B_{12} injections, MNA is expected to

meet the MCLs or residential RBCs for COCs within 20 years.

Alternative 7: Pump-and-treat at all locations

Estimated Capital Cost: $1,494,890
Estimated Present Worth O & M Cost: $5,005,110
Estimated Total Present Worth Cost: $6,500,000
Estimated Time to Achieve RAOs: Indeterminate length of time due to possible DNAPL

Alternative 7 consists of groundwater pump-and-treat for all of the surficial and middle aquifers where VOC contamination exceeds 5 µg/L. The extracted groundwater will be treated above ground using conventional technologies such as air stripping and carbon adsorption, and discharged to the Gunpowder River under NPDES equivalency permit with discharge parameters approved by MDE. Compliance monitoring (documentation of the plume configuration and concentration) will consist of sampling compliance wells for VOCs, and the groundwater extraction wells for VOCs and iron quarterly during the first two years. Subsequently, the compliance wells and the extraction wells will be sampled annually during years three through five, and bi-annually thereafter. Throughout operation of the system, influent and effluent groundwater samples will be collected from the air-stripping/adsorption system on a quarterly basis and analyzed for VOCs. Similarly, vapor samples will be collected before and after the granular activated carbon units and analyzed for VOCs to evaluate system performance.

A potential problem with pump-and-treat technology at this site is that contaminants, particularly DNAPL, may continue to desorb from soil matrix once the treatment is stopped, and rebound to concentrations above the clean-up criteria. Therefore, the time required for the operation of pump-and-treat alone is indeterminate, and the long-term O&M costs may become substantial. The pumping of the diluted plume will continue until MCLs or residential RBCs for COCs are achieved. A groundwater monitoring plan will be specified in the design workplan.

Alternative 8: Pump-and-treat in areas greater than 1,000 µg/L (both aquifers); LTM at all other locations

Estimated Capital Cost: $801,934
Estimated Present Worth O & M Cost: $2,208,066
Estimated Total Present Worth Cost: $3,010,000
Estimated Time to Achieve RAOs: Indeterminate length of time due to possible DNAPL

Alternative 8 consists of groundwater pump-and-treat for all of the surface and middle aquifers where VOC concentrations are above 1,000 µg/L and LTM where concentrations are below 1,000 µg/L. Land use restrictions (described in Alternative 2) will be enforced to prevent exposure to groundwater contaminants until remediation goals are achieved, if achievable under this alternative.

The groundwater extraction and treatment component of Alternative 8 is similar to that of Alternatives 4, 5, and 7, capturing groundwater with VOC concentrations greater than 1,000 µg/L. The extracted groundwater will be treated above ground using conventional technologies such as air stripping and carbon adsorption, and then discharged to the Gunpowder River under NPDES equivalency permit with discharge parameters approved by MDE. As described in Alternative 7, evaluation of the system performance will include monitoring of compliance wells, extraction wells, influent and effluent groundwater samples of the air-stripping/adsorption system, and vapor samples after the vapor phase granular activated carbon units. LTM, to be specified in the design workplan, will be instituted to assess the impact on the dissolved phase plume in response to the source control pumping, and any naturally occurring attenuation process.

As discussed for Alternative 7, pump-and-treat systems are known to potentially fail in areas where residual products and DNAPLs are present, as is suspected at Graces

Quarters. In addition, VOCs in areas where their concentrations are below 1,000 µg/L, but still above their regulatory cleanup levels, will remain largely untreated by this alternative and may not be contained during the anticipated long treatment duration. This alternative, therefore, may not meet the performance standard of MCLs or residential RBCs for COCs.

Alternative 9: ERH in areas greater than 1,000 µg/L in the surficial aquifer; pump-and-treat at all other locations

Estimated Capital Cost: $3,038,504
Estimated Present Worth O & M Cost: $6,861,496
Estimated Total Present Worth Cost: $9,900,000
Estimated Time to Achieve RAOs: 30 years

Alternative 9 involves using ERH for remediation of the surficial aquifer where VOC concentrations exceed 1,000 µg/L. For areas in the surficial aquifer where VOC concentrations are below 1,000 µg/L, and for the entire plume in the middle aquifer, pump-and-treat will be used. This technology uses low-frequency electricity delivered to three electrodes in a triangular array to uniformly heat the target area to the boiling point of water, converting the subsurface moisture (groundwater) and contaminants to steam and vapor. The steam and vapor are extracted via conventional extraction technologies such as soil vapor extraction and are treated on site. Three-phase electricity can be obtained from the existing power source that runs to the vitamin B_{12} pilot study building (APG, 2002). The expected maximum temperature in the target area (100,000 ft^2) will be 100 to 112 degree Celsius (^oC) and the estimated power required to operate the system is 9,250,000 kilowatt hours (kW-hr). ERH technology, however, is not suitable for the middle aquifer because of the difficulties involved with placing electrodes in the middle aquifer and collecting the steam and vapors.

Possible concerns with ERH are the potential for releases of hazardous vapors to the atmosphere, the potential remobilization of DNAPLs into the aquifer due to decreased viscosity, and physical hazards associated with high voltage and high temperatures. The latter may potentially explode the UXO, if present, and melt polyvinyl chloride (PVC) materials that are commonly used for monitoring wells in the subsurface.

The pump-and-treat component of this alternative will be similar to that described in Alternatives 4, 5, 7 and 8. The extracted groundwater will be treated above ground using conventional technologies such as air stripping and carbon adsorption, and then discharged to the Gunpowder River under NPDES equivalency permit with discharge parameters approved by MDE. Evaluation of the system performance will include monitoring of compliance wells, extraction wells, influent and effluent groundwater samples of the air-stripping/adsorption system, and vapor samples after the vapor phase granular activated carbon units. The monitoring program will be specified in the design workplan. The pumping of the diluted plume will continue until MCLs or residential RBCs for COCs are achieved.

EVALUATION OF REMEDIAL ALTERNATIVES

In evaluating the remedial alternatives for Operable Unit A, the potential performance of each alternative is evaluated in terms of the nine evaluation criteria required by the NCP:

- protection of human health and the environment;
- compliance with ARARs;
- long-term effectiveness;
- reduction of toxicity, mobility, and volume of chemicals through treatment;
- short-term effectiveness;
- implementability;
- cost;
- state acceptance; and
- community acceptance.

The nine criteria are categorized into one of three groups: **threshold criteria, primary balancing criteria, or modifying criteria**. (These criteria and the nine sub-criteria are defined at the end of this document).

The alternative selected must satisfy the threshold criteria, which are of primary importance. The primary balancing criteria are used to weigh the major tradeoffs among the alternatives, and the modifying criteria are considered after the public has commented on the Proposed Plan.

Threshold Criteria

Overall Protection of Human Health and the Environment

Alternative 1 (no action) may not provide adequate long-term protection of human health because no restrictions are assumed to be in place to prevent future use of the contaminated groundwater at the site. Although the site is on Department of Defense (DOD) property, this alternative assumes that land use restrictions will not be enforced. Groundwater monitoring will not be conducted, so no data will be available to evaluate contamination concentrations and migration.

Alternatives 2 through 9 are considered protective of human health because land use restrictions will prohibit future use of groundwater from the Primary Test Area and Alternatives 3 through 9 provide for remediation of the groundwater. These alternatives vary, as detailed in the FS Report, with respect to long-term protection of human health and the environment (APG, 2003). Overall, Alternative 6 receives the best rating for this criterion due to its aggressive treatment of almost the entire plume (at a proportionally larger cost). Alternatives 3, 4, 5, 7, and 9 receive a good rating. Alternatives 2 and 8 receive an adequate rating while Alternative 1 a poor rating.

Compliance with ARARs

The MCLs for the COCs are relevant and appropriate requirements. Based on the high formation permeability, the natural water quality and low total dissolved solids, the aquifers beneath the Primary Test Area are classified by the State of Maryland as Type I (COMAR 26.08.02.09). The EPA classifies both the unconfined and middle aquifers as Type IIB based on yield, total dissolved solids, and the quality.

Existing contaminants must be treated to below MCLs and risk based standards (i.e., 1,1,2,2-tetrachloroethane) in order for the groundwater to serve as a source of water supply. Alternatives 1 and 2 receive the lowest rating for this criterion because they do not meet the Federal ARARs to clean up the groundwater to MCLs. Alternative 8 also receives a low rating because groundwater in areas where LTM is used may still contain VOCs at concentrations above their regulatory cleanup criteria. The remaining alternatives all receive an excellent rating. Alternatives 3, 4, 5, and 6 (involving injection of substrates into the ground) are expected to achieve the MCLs for the chlorinated solvents. However, injection may result in temporary increases in arsenic concentrations above the MCL, total dissolved solid concentrations above the Type I groundwater standards, and titanium in groundwater above its RBC in the treatment zone. It is unclear whether groundwater titanium levels will be above the associated RBC. Pilot testing conducted to date indicates each of these effects is localized and temporary (concentrations are naturally reduced over time). Downgradient monitoring for these parameters will be specified in the design workplan.

Alternatives 7 and 9 will comply with all pertinent ARARs and “To be considered” (TBC) criteria. It is important to note, however, that if residual product is present in the source areas, pump-and-treat alone will not remediate these areas to MCLs or other approved cleanup criteria. The pump-and-treat component of Alternatives 4, 5, 7, 8 and 9 will need to comply with applicable Maryland Air Quality Regulations, NPDES regulations, and hazardous waste requirements for spent carbon.

Primary Balancing Criteria

Long-term Effectiveness and Permanence

The long-term effectiveness and permanence criterion considers the magnitude of the residual risk that would remain after the implementation of an alternative, and the adequacy and reliability of the controls instituted. Alternative 1 is not evaluated further in this section, as it does not meet the threshold criteria for protection of human health and the environment and compliance with ARARs. The rest of the alternatives, Alternatives 2 through 9, include land use restrictions to prevent groundwater use and groundwater monitoring to document the size and concentrations of the plumes. Alternative 2, however, does not remediate the groundwater and thus is not considered a permanent solution.

The vitamin B_{12} component of Alternatives 3, 4, 5, and 6 will result in reductive dehalogenation of the contaminants, which is an irreversible process that decreases the degree of chlorination under reducing conditions ultimately to ethene, ethane, or methane. For Alternatives 3 and 6, natural attenuation processes will help ensure that the chlorinated constituents outside the treatment areas are reduced over time to acceptable levels. Natural attenuation processes will lead to permanent reduction in chlorinated solvent concentrations as attenuation progresses.

Pump-and-treat systems included in Alternatives 4, 5, 7, 8 and 9 have been used at hundreds of remediation sites with proven long-term effectiveness in terms of hydraulic control and surface treatment. For each of these alternatives the plume will be contained by the extraction wells until RAOs are achieved. A potential problem with pump-and-treat is that contaminants may rebound once the treatment has ceased, or if residual product remains in the subsurface. RAOs may not be achievable with this technology alone.

Alternative 9 includes ERH in addition to pump-and-treat. ERH is an irreversible process that volatizes or hydrolyzes contaminants and extracts them via soil-vapor extraction wells. A pilot test, however, will be required to verify the effectiveness of this approach, the design assumptions (e.g., electrode spacing), and the electrical power requirements that may be significant.

Overall, Alternatives 6 and 9 receive an excellent rating due to their aggressive treatment of the contaminant plume (at proportional costs). Alternatives 3, 4, 5 and 7 receive a good rating for long-term effectiveness and permanence. Alternative 2 receives an adequate rating because no treatment occurs. Alternative 8 receives a poor rating because contaminants in areas where LTM is applied may still be present at concentrations above their regulatory cleanup levels and remain untreated.

Reduction in Toxicity, Mobility, and Volume

Under Alternative 2, natural attenuation processes in the groundwater may slowly reduce the toxicity of the groundwater contamination over time. The vitamin B_{12} component of Alternatives 3, 4, 5, and 6 will result in reduction of groundwater toxicity from chlorinated solvent constituents, but may temporarily increase arsenic concentrations in groundwater within the treatment zone. The extent to which arsenic is mobilized will be driven by aquifer redox chemistry. Should the soluble, reduced form of arsenic be transported to an aerobic portion of the aquifer, the arsenic will be oxidized and precipitated. Under lower redox conditions, the arsenic may co-precipitate with iron. Thus, the potential extent of arsenic migration will be naturally limited.

The pump-and-treat component of Alternatives 4, 5, 7, 8 and 9 will effectively contain and extract the contaminated groundwater hence decreasing its toxicity, mobility, and volume. However, pump-and-treat may have limited effect on areas of the aquifer where residual product remains. The air stripper and carbon adsorption units will remove the strippable and non-strippable contaminants from the groundwater. Constituents transferred to activated carbon will subsequently be

destroyed when the carbon is thermally regenerated.

The ERH component of Alternative 9 will result in reduction of groundwater toxicity as contaminants are volatilized and extracted by the soil-vapor extraction wells. Overall, Alternative 2 receives a poor rating in this category, Alternatives 3, 4, and 6 have an excellent rating, while Alternatives 5, 7, 8 and 9, relying heavily on pump-and-treat receive a good rating.

Short-term Effectiveness

Alternative 2 does not include groundwater remediation, and thus, the time required to achieve RAOs is undefined. For Alternatives 3, 4, 5, and 6, the chemical injection of vitamin B_{12} concentrate is estimated to be completed within a year. The rate at which the chlorinated solvent plume not subjected to direct treatment is attenuated under Alternatives 3 and 6, will be dependent on the extent to which reducing conditions are established through transport of the injected chemicals, and the natural rate of attenuation achieved through physical mechanisms in the aquifer following source control activities (vitamin B_{12} treatment). The natural attenuation portion of Alternatives 3 and 6 are conservatively estimated to take 30 and 20 years, respectively, to achieve the RAOs. Alternative 6 is estimated to take less time than Alternative 3 because the vitamin B_{12} injection covers a much larger area of the plume for Alternative 6.

For Alternatives 4, 5, 7, 8 and 9, the rate at which pump-and-treat remediates the aquifers will be controlled by the rate of desorption of the chlorinated constituents from aquifer media. Alternative 4, which includes vitamin B_{12} treatment for source area reduction in both aquifers and with pump-and-treat, is conservatively estimated to achieve RAOs in 20 years. Alternatives 5 and 9 only include “source area” reduction (via vitamin B_{12} treatment or ERH) in the surficial aquifer along with pump-and-treat, and are conservatively estimated to achieve RAOs in 30 years. ERH (Alternative 9) is predicted to achieve “source area” reduction within 1 year, however a pilot scale test would be required to verify this estimate. Alternatives 7 (pump-and-treat) and 8 (pump-and-treat along with MNA) are estimated to take at least 30 years to achieve the RAOs and may not be effective in the source areas.

Overall, Alternatives 4 and 7 receive the highest short-term effectiveness rating. Alternatives 3, 5, 6, 8 and 9 each receive a good rating and Alternative 2 receives an adequate rating.

Implementability

There are three main factors considered for this criterion: technical feasibility, administrative feasibility and availability of services and materials. Alternatives 2 through 9 are administratively feasible and the required services and materials are available. Technical feasibility therefore is the focus of the implementability analysis. Alternative 2 has no implementability considerations because there is no construction associated with this alternative and therefore receives an excellent rating in this category.

Installation of the infrastructure for the vitamin B_{12} treatment, pump-and-treat, and ERH technologies should not be difficult. Proper precautions are necessary when performing any intrusive work due to UXO on-site. The primary technical issue regarding the vitamin B_{12} treatment component of Alternatives 3, 4, 5 and 6 is the on-site generation of titanium citrate (reducing agent), because it cannot be purchased (assuming titanium citrate is the reducing agent ultimately used). The O&M of the vitamin B_{12} system will require two full-time operators for one year, and is expected to be more intensive than the other technologies. However, it is expected that treatment with vitamin B_{12} will be for one year only.

Technical issues associated with ERH include the transfer of heat to the subsurface and the collection of steam and vapors. The presence of UXO may result in an explosive hazard due to the high soil temperatures. The shallow depth of the treatment target area may make it harder for the vapor

extraction system to capture all of the vapors and prevent hazardous vapor release to the atmosphere. ERH technology can be operated with one part-time operator. However, a pilot test would be required for this technology to demonstrate its implementability.

The pump-and-treat components of Alternatives 4, 5, 7, 8 and 9 present no technical implementability issues because this is a well developed technology. Overall, Alternatives 2 and 3 receive the highest rating (excellent) in this category. Alternatives 4, 5, 6, 7, 8 each are classified as good. Alternative 9 may have some implementability issues and was classified as adequate in this category.

Cost

Alternative 2 provides no remediation but does include LTM and has an estimated total cost of $400,000. Alternatives 3, 7 and 8 are the next most cost effective, with an estimated total net present worth costs of $5,700,000, $6,500,000 and $3,010,000, respectively. Alternatives 9 and 6 are the most expensive with estimated net present worth costs of $9,900,000 and $14,300,000, respectively.

The major cost component of the vitamin B_{12} treatment technology is the labor expense and chemical cost to produce the vitamin B_{12} concentrate. The costs associated with producing the concentrate, the frequency of concentrate injections, the number of injection locations, and the duration of the concentrate injection period drive the estimated costs for Alternatives 3, 4, 5 and 6. For each of these alternatives, assuming all other parameters stay the same, increasing the period of concentrate injection from one year to two years would increase the costs by approximately 40 to 60 percent. Increasing or decreasing the area to be remediated will significantly affect the cost to operate the vitamin B_{12} treatment but will have less of an affect on the pump-and-treat costs.

The number of years required for the pump-and-treat system to achieve the RAOs is a major cost uncertainty for Alternatives 4, 5, 7 and 8. Overall, Alternative 2 receives the highest rating (excellent) in this category because it does not require capital spending. Alternative 3, 7 and 8 each ranks as good. Alternatives 4, 5, and 9 are rated adequate, with Alternative 6 ranked poor.

Modifying Criteria

State Acceptance

The MDE, Waste Management Administration concurs with the selected alternative.

Community Acceptance

Community acceptance of the alternatives will be evaluated after the public meeting and will be described in the ROD.

PREFERRED ALTERNATIVE FOR OPERABLE UNIT A

Alternative 3 is preferred as it provides good overall protection of human health and the environment; provides long- and short-term effectiveness; reduces the toxicity, mobility and volume of hazardous constituents through treatment; complies with all ARARs; and has been demonstrated to be implementable.

Alternative 3 involves treating areas with VOC concentrations greater than 1,000 µg/L with vitamin B_{12} concentrate and using MNA where concentrations are less than 1,000 µg/L. Land use restrictions will be enforced to prevent exposure to groundwater contaminants until remediation goals are achieved. The vitamin B_{12} concentrate will be introduced into the subsurface via recirculation wells or other alternative methods such as direct injection or injection through standard wells. A vitamin B_{12} catalyzed reductive dehalogenation pilot test has already demonstrated that the technology is particularly effective in degrading chlorinated solvent concentrations to low levels (APG, 2001b).

Alternative 3, particularly, is consistent with the EPA's guidance to use treatment to destroy principal threats and stimulated

natural attenuation to address non-principal threats (e.g., dilute VOC plume). Alternative 3 involves treating areas with VOC concentrations greater than 1,000 µg/L with vitamin B_{12} concentrate and using MNA where concentrations are less than 1,000 µg/L. Institutional controls such as land use restrictions will be implemented at the Primary Test Area during the course of the vitamin B_{12} treatment and MNA monitoring program. Appropriate access controls will include warning signs, and land and water patrols. Land use restrictions will include prohibitions of residential or military residential housing, and extraction/use of groundwater. Annual site inspections will be conducted to ensure these institutional controls are in place.

Vitamin B_{12} treatment will produce the fastest remediation of the contaminated plume in both the surficial and middle aquifers. Due to the large cost of producing the vitamin B_{12} concentrate, methods of reducing vitamin B_{12} use such as pulsed injection will be considered as a means of reducing costs. In addition, compounds such as molasses and corn syrup may potentially accelerate *in-situ* biodegradation of chlorinated VOCs and further reduce cost by simplifying the process.

Following the introduction of vitamin B_{12} into the aquifer, highly chlorinated VOCs presented in the vicinity of the vitamin B_{12} injection area will be reduced to less chlorinated forms, which will subsequently degrade via abiotic or biotic reactions. Evaluation of site data has indicated that MNA used as a follow-up in the lower concentration portions of the contaminant plume, after active remedial actions have been taken in areas with high concentration of VOCs, will be effective (APG, 1999). Therefore, Alternative 3 should significantly reduce the potential for off-site migration of chlorinated hydrocarbons, decreasing the contaminant concentrations in the source areas to below 100 µg/L within a relatively short time. The performance standards for this alternative will be restoration of the aquifer to beneficial use (COCs at or below MCLs/RBCs) at the conclusion of the MNA portion of the remedy, estimated at 20 to 30 years. The monitoring requirements, including frequency, to measure the progress of the remedy will be specified in the design workplan. Land use controls that prohibit consumption of the groundwater during the remedy will also be specified in the design workplan for Operable Unit A.

Based on information currently available, the lead agency believes the Preferred Alternative -- Alternative 3 -- meets the threshold criteria and provides the best balance of tradeoffs among the other alternatives with respect to the balancing modifying criteria. The Army expects the Preferred Alternative to satisfy the following statutory requirements of CERCLA 121 (b): 1) be protective of human health and the environment; 2) comply with ARARs; 3) be cost-effective; 4) utilize permanent solutions and alternative treatment technologies to the maximum extent practicable; and 5) satisfy the preference for treatment as a principal element.

COMMUNITY PARTICIPATION

The Army, EPA, and MDE are soliciting input from the community on each of the proposed alternatives for the Primary Test Area (Operable Units A), Graces Quarters. The comment period extends from April 14, 2004 through May 29, 2004 (45 days). This period includes a public meeting at which the Army, EPA and MDE will present the Proposed Plan and accept both oral and written comments.

APG invites the public to attend a meeting at which representatives from APG, EPA, and MDE will be available to discuss the Proposed Plan in further detail and answer any questions.

Date: April 27, 2004

Information/poster Session: 6:30 p.m. to 7:15 p.m.

Proposed Plan Presentation: 7:15 p.m.

Venue: Marshy Point Nature Center
7130 Marshy Point Road
Baltimore, MD 21220

Comments and responses will be summarized in the ROD, which is the document that presents the selected remedy. To send written comments or obtain further information, contact any of the following representatives:

Mr. Kenneth Stachiw, Program Manager
Directorate of Safety, Health & Environment
ATTN: AMSSB-GSH-ER
5179 Hoadley Road
Aberdeen Proving Ground, MD 21010
(410) 436-3320

Mr. Frank Vavra
US Environmental Protection Agency,
Region III
1650 Arch Street (3HS13)
Philadelphia, PA 19103-2029
(215) 814-3221

Mr. Curtis DeTore
Maryland Department of the Environment
Federal/Superfund Division
1800 Washington Blvd., Suite 650
Baltimore, MD 21230-1719
(410) 537-3791

Written comments must be postmarked no later than the last day of the public comment period, which is May 29, 2004.

REFERENCE

AEHA. 1989. Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA), Edgewood Area, Aberdeen Proving Ground, Maryland, AEAA.

APG (Aberdeen Proving Ground). 2003. Graces Quarters, Aberdeen Proving Ground, Edgewood, Maryland. Feasibility Study, Operable Unit A: Groundwater-Final. Report prepared by URS Group, Inc. for AimTech and Environmental Conservation and Restoration Division. Installation Restoration Program, December 2003.

APG (Aberdeen Proving Ground). 2001a. Chemical Warfare Materiel and Other Hazardous Substances (Operable Unit B) and Associated Sites -- Record of Decision. Carroll Island and Graces Quarters, Aberdeen Proving Ground, Maryland. May 2001.

APG (Aberdeen Proving Ground). 2001b. Graces Quarters, Aberdeen Proving Ground, Maryland. Vitamin B12-catalyzed Reductive Dechlorination Pilot Test Report. December 2001.

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APG (Aberdeen Proving Ground). 1998b. Additional Groundwater Investigations Data Report, Aberdeen Proving Ground, Maryland. Installation Restoration Program, January 1998.

Bennet, R. R., Meyer, R. R. 1952. Geology and Groundwater Resources of the Baltimore Area, Maryland Department of Geology, Mines and Water Resources, Bulletin 4, 573p.

USGS. 2001. Simulation of Groundwater Flow and Transport of Chlorinated Hydrocarbons at Graces Quarters, Aberdeen Proving Ground, Maryland. Tenbus, F. J., Fleck, W. USGS Water Resources Investigations Report 01-4106, USGS, Denver, Colorado, 51p.

ACRONYMS AND ABBREVIATIONS

APG	Aberdeen Proving Ground
APGSCC	Aberdeen Proving Ground Superfund Citizens Coalition
ARAR	Applicable or relevant and appropriate requirement
bgs	Below Ground Surface
BRA	Baseline Risk Assessment
CA	Chloroethane
CAHs	Chlorinated Aliphatic Hydrocarbons
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COCs	Constituents of Concern
COPCs	Constituents of Potential Concern
CS	Ortho-chlorobenzolmalonoitrile
CWM	Chemical Warfare Materiel
DSERTS	Defense System Environmental Restoration Tracking System
DNAPL	Dense Non-Aqueous Phase Liquid
DOD	Department of Defense
EM	Electromagnetic Conductivity
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
ERH	Electrical Resistance Heating
°C	Degree Celsius
FS	Feasibility Study
ft	Feet
GB	Isopropylmethylphosphonofluoridate
GD	Pinacolylmethylphosphonofluoridate
GMS	Groundwater Modeling System
GPR	Ground-Penetrating Radar

ACRONYMS AND ABBREVIATIONS (cont'd)

HD	2,2'-dichlorodiethyl Sulfide (mustard gas)
HI	Hazard Index
kW-hr	Kilowatt Hour
LECR	Lifetime Excess Cancer Risk
LTM	Long-term Monitoring
MDE	Maryland Department of the Environment
MNA	Monitored Natural Attenuation
NCP	National Contingency Plan
NGVD	National Geodetic Vertical Datum
NPL	National Priorities List
ppb	Part Per Billion
PVC	Polyvinyl Chloride
RA	Risk Assessment
RAB	Restoration Advisory Board
RAO	Remedial action objective
RBC	Risk Based Concentration
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
TBC	To be Considered
µg/L	Microgram per Liter
UXO	Unexploded Ordnance
VOC	Volatile Organic Compound
VX	o-ethyl-s-(2-diisopropylaminoethyl) methylphosphonothioate

EXPLANATION OF EVALUATION CRITERIA

I. THRESHOLD CRITERIA

- **Overall Protection of Human Health and the Environment** refers to whether a remedy provides adequate protection against harmful effects. It calls for consideration of how human health or environmental risks are eliminated, reduced, or controlled through treatment, engineering controls, or institutional controls.

- **Compliance with applicable or relevant and appropriate requirements** (ARARs) addresses whether a remedy meets all the applicable or relevant and appropriate requirements of other federal and state environmental statutes.

II. PRIMARY BALANCING CRITERIA

- **Long-term effectiveness and permanence** refers to the magnitude of residual risk and the ability of a remedy to maintain reliable protection of human health and the environment after cleanup goals have been met.

- **Reduction of toxicity, mobility, or volume** through treatment refers to the effectiveness of the treatment technologies in reducing the toxicity, mobility, or volume of contaminants.

- **Short-term effectiveness** refers to the speed with which the remedy achieves protection and to the remedy's potential during construction and implementation to have adverse effects on human health and the environment.

- **Implementability** refers to the technical and administrative feasibility of a remedy, including the availability of required materials and services.

- **Cost** includes capital expenditures and operation and maintenance costs.

III. MODIFYING CRITERIA

- **State acceptance** indicates whether the state concurs with, opposes, or has no comment on the preferred alternative based on its review of the RI/FS report and Proposed Plan.

- **Community acceptance** is documented in the Record of Decision following a review of public comments on the Proposed Plan.

GLOSSARY OF TERMS

Administrative Record - This is the collection of documents that were referred to or relied upon to support a decision document or enforcement action, including information and reports generated during the site investigation and remediation. It is available for public review.

Applicable or Relevant and Appropriate Requirements (ARARs) - These are **requirements** set forth by federal and state environmental statutes and regulations which must be met in the implementation of remedial alternatives.

Chemical Warfare Materiel (CWM) - This refers to chemical agents (i.e., chemical compounds such as nerve, blister, blood, choking, and incapacitating agents) that, through chemical properties, produce lethal or damaging effects on humans as well as other chemical compounds such as riot control agents.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) - This federal law was passed in 1980 and amended in 1986, and is commonly referred to as the Superfund Law. It provides for liability, compensation, cleanup, and emergency response in connection with the cleanup of inactive hazardous waste disposal sites that endanger public health and safety or the environment.

Feasibility Study (FS) - This provides a detailed analysis of remedial alternatives for a site. This analysis supports risk management decision processes to select the most appropriate remedy.

National Contingency Plan (NCP) - Officially the National Oil and Hazardous Substances Pollution Contingency Plan, these regulations give the federal government the authority to respond to the problems of abandoned or uncontrolled hazardous waste disposal sites as well as to certain incidents involving hazardous wastes.

National Priorities List (NPL) - This list, developed by EPA, identifies the uncontrolled hazardous substance release sites in the United States that are considered priorities for long-term remedial evaluation and response.

Net Present Worth - The amount of money (in 2004 dollars) necessary to secure the promise of future payments, or series of payments, at an assumed interest rate. For example, the net present worth of a loan is the amount of money one would need to invest now to generate the future series of payments.

Remedial Action Objectives (RAOs) - Medium-specific goals for protecting human health and the environment, which can be achieved by reducing exposure (e.g., capping an area or limiting access) as well as by reducing the level of constituents of concern.

Record of Decision (ROD) - This record is signed by the Army and EPA. It provides the cleanup action or remedy selected for a site, the basis for selecting that remedy, public comments on alternative remedies, responses to comments, and the cost of the remedy.

Remedial Investigation (RI) - The purpose of a remedial investigation is to characterize possible contamination and to identify sites that may require remedial action.

Resource Conservation and Recovery Act (RCRA) - An act, enacted in 1976, which established the first comprehensive federal regulatory program for controlling hazardous waste at active sites. This act also provided grants and technical assistance to the states to help improve their waste management techniques.

Superfund Amendments and Reauthorization Act (SARA) - This Act amended CERCLA in 1986.

Surveillance Testing - An investigation to determine the response of chemical materials to a variety of environmental conditions, including the stability of these materials under various temperature and humidity conditions.

Unexploded Ordnance (UXO) - Any item that contains explosives or propellant that, when fired, did not detonate (or burn) as designed. It may include mortars, rockets, grenades, chemical warfare material, bombs, artillery shells, landmines, and incendiary and pyrotechnic materials.